BRIEF ACCOUNT

OF A

NEW INVENTION,

For which has been obtained his MAJESTY's Royal Letters Patent.

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Publiſhed by the PATENTEE,

CHRISTOPHER CHRYSEL.

BRISTOL:

Printed by WILLIAM PINE, M.DCC.LXXIV.

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WHEREAS I have obtained his Majeſty's Letters Patent, for my new invention of conſtructing and ſetting the boilers of any dimenſions in fire-engines, ſalt-works, brewhouſes, diſtilleries, ſugar-houſes and ſugar-works; and alſo in allum, coperas, Roman-vitriol, and ſaltpetre-works, in ſuch a well-contrived manner, that not only is obtained a quicker and greater diſpatch of buſineſs, but alſo ſaved more than the half part of the coal and fuel otherwiſe uſed therein; and hereof by eſpecial grace granted to me the ſole and whole uſe, exerciſe, practice and vend, with all the profit, benefit, commodity and advantages from time to time coming, growing, accruing and ariſing from the ſaid invention, in that part of his Majeſty's kingdom of Great Britain, called England, the dominions of Wales, and town of Berwick-upon-Tweed; and alſo in his Majeſty's colonies and plantations abroad, for the full end and term of fourteen years: and to the end, that I may have and enjoy the full benefit, and the ſole uſe and exerciſe of the ſaid invention, according to his Majeſty's gracious intent before declared; his Majeſty doth alſo require and ſtrictly command all and every perſon or perſons, bodies politic and corporate, and all other his ſubjects whatſoever, within the ſaid part of his kingdom of Great Britain, called England, the dominions of Wales, and town of Berwick-upon-Tweed, and in his colonies and plantations abroad aforeſaid, that neither they nor any of them, at any time during the continuance of the ſaid term of fourteen years granted, either directly or indirectly, do make uſe and put in practice the ſaid invention, or any part of the ſame; nor in any wiſe counterfeit, imitate,

or reſemble the ſame; nor ſhall make, or cauſe to be made, any addition thereunto or ſubtraction from the ſame, whereby to pretend himſelf or themſelves the inventor or inventors, deviſor or deviſors thereof, without the licence, conſent and agreement of me, in writing under hand and ſeal firſt had and obtained in that behalf, upon ſuch pains and penalties as can or may be juſtly inflicted on ſuch offenders for their contempt of his Royal command, and further to be anſwerable to me according to law for his or their damages occaſioned. Moreover it is therein commanded, all and ſingular the juſtices of the peace, mayors, ſheriffs, conſtables, headboroughs, and all other officers and miniſters whatſoever, that they or any of them do not, nor ſhall at any time hereafter during the ſaid term, in any wiſe moleſt, trouble or hinder me, my agents, deputies, and ſervants, in or about the due and lawful uſe or exerciſe of the ſaid invention, or any thing relating thereto, &c. I therefore think it proper and neceſſary, to give to the public a brief account and demonſtration of the ſaid my new invention, that every one may form a due idea of its uſe, and of the benefits reſulting therefrom, according to the diſcoveries by ſeveral trials and expenſive experiments made thereof privately.

The intents and purpoſes of boiling great quantities of water and liquors in large veſſels are very different. In great launderies and brewhouſes it is the purpoſe and intent ſolely to boil at once great quantities of water, for the uſe of waſhing and brewing; in ſalt-works, ſugar-houſes, and ſugar-works; and alſo in allum, coperas, Roman-vitriol, and ſaltpetre-works, it is the intent and purpoſe not only to boil a large quantity of brine, ſweet juices and acid lees, but principally to drive off from a large quantity of them the ſuperfluous moiſture into ſteam, that the ſalt may ſhoot into cryſtals, the ſweet ſugar-juices come to a due conſiſtence, and the acid lees be brought to that temperament required for

the

the cryſtalliſation of allum, coperas, Roman-vitriol, and ſaltpetre; and likewiſe in diſtilleries, to drive out of a large quantity of fermented maſh the ſpirit in a ſteam, and through the worm into the receiver. But at the fire-engines, it is the intent and purpoſe ſolely to raiſe from boiling water, a ſufficient quantity of ſteam for filling the cylinder to counterbalance the preſſure of the atmoſphere, that the piſton may riſe and aſcend. &c.

Nevertheleſs they all agree together, reſpecting the great utility of obtaining the quickeſt diſpatch, the ſhorteſt time, and the ſmalleſt quantity of fuel poſſible. And about this, great numbers have ſpared no time, pains or trouble to find out a ſaving of time and fuel in all the fore-mentioned different intents and purpoſes, or at leaſt in one or the other, but without ſucceſs; and they all go on the old way ſtill, which is very heavily felt at the fire-engines on mines, and the waſte of incredible quantities of coals is complained of.

If we now deſire to obtain our wiſhes, in faving both time and coals in all the fore-mentioned different intents and purpoſes, then we muſt be very attentive to the minuteſt circumſtances, and call to our help the experience derived from numerous experiments and trials made partly by ourſelves, partly obſerved by others. In matters before us we find by experience, that large boilers, coppers or pans, three or four feet deep, with water or other liquors, do always require a very long time and a large quantity of fuel to make and keep them boiling. On the contrary, the leſs the depth of water or liquor, the ſooner, and by leſs fuel the boiling will be obtained and continued. A cylindrical veſſel filled with water 3 inches deep, will boil quicker, and with far leſs fuel than when it is filled 6 inches deep; and this alſo will boil quicker and with leſs fuel than when it is filled one foot deep; and this will boil quicker and by leſs fuel, than when it is filled 2, 3 and 4 feet deep. The flue round about ſuch a

veſſel

veſſel is frequently of but very ſmall help, becauſe the natural tendency and energy of the fire is always perpendicularly upwards, and then the ſtrongeſt, and hath therefore the greateſt force and power, when it is under the bottom of the veſſel, but very weak about the ſides. A burning candle can convince every one thereof; if we put our finger near the ſide of the flame, we can come very near, and almoſt touch it before we feel any heat and fire; but if we bring the finger or hand perpendicularly above it, though three or four inches high, we cannot ſuffer it one minute without being burnt.

Therefore it is moſt conducible and advantageous to enlarge the quantity of water or liquor in a convenient length and breadth: That is to ſay, to change the deep coppers and pans, into ſhallow boilers of an agreeable length and breadth, containing either the ſame quantity of water and liquors, or double, treble, or quadruple that quantity, according to the intents and purpoſes; and in each and every ſuch caſe the boiling will be obtained almoſt in one and the ſame time, and by one and the ſame quantity of fuel, notwithſtanding the different dimenſions of the ſhallow boilers in length and breadth, which alſo will ſucceed far better and quicker, when certain particulars are obſerved, which I do ſpare for a diſcovery by mouth.

Many might think, that in ſuch ſhallow boilers there could not be boiled ſuch a great quantity of water or liquors, as in a deep boiler, copper or pan; but I will make the contrary evident, and take for an example a boiler, copper or pan of four feet diameter and depth, which will contain 288 gallons and no more. If it is changed into a ſhallow boiler 8 feet in length, 7 feet in breadth, and one foot deep, it will contain 336 gallons; but let it be 12 feet in length, and 10 feet in breadth, and one foot deep, it will contain 726 gallons; and when it is 20 feet in length, and 10 feet in breadth, and one foot deep, it will contain 1260 gallons,

gallons, a great deal more than in the boiler, copper or pan mentioned above. This may be conſidered by the proprietors of great brew-houſes, whether they could not reap hereby great advantages in their buſineſs, eſpecially in regard of making ſhip-mum, which cannot be done in large coppers and deep boilers, nor by ſtrong boiling, but ſolely in ſhallow boilers, being conſtructed and ſet according to my invention deſcribed below.

If we do further conſider the boilers in ſalt-works, ſugar-houſes, and ſugar-works; and alſo in allum, copperas, Roman vitriol and ſalt petre-works, wherein the principal intent and purpoſe, is to drive off the ſuperfluous water into ſteam, that the ſalt may ſhoot into cryſtals, and be raked out, the ſweet juices inſpiſſated, and brought to its due conſiſtence; and alſo the acid lees evaporated to the due temperament, required for the cryſtalliſation of allum, copperas, Roman vitriol and ſalt petre, there my changing of the deep boilers into ſhallow boilers, will be of the greateſt ſervice and benefit. Becauſe in all the above-mentioned works, it is the principal intent and purpoſe, to drive off the ſuperfluous water into ſteam; and the more ſteam can be driven off, the ſooner the buſineſs is finiſhed. But the quantity of ſteam doth ſolely depend upon the extent of the ſurface, and by no means upon the depth of the boiling-water or liquor, which latter doth retard the operation, and requires more time and fuel. Now a common boiler, copper or pan of four feet depth and diameter, is no more then 12 ſquare feet ſurface, and there cannot riſe more ſteam, than what can poſſibly riſe from 12 ſquare feet ſurface. On the contrary, a ſhallow boiler 8 feet in length, 7 feet in breadth, and one foot deep, hath 56 ſquare feet ſurface, and there muſt riſe above four times as much ſteam; and conſequently the buſineſs done in a fourth of the time, and by four times leſs fuel; that in the ſame time the common boiler, copper or pan of 4 feet

diameter and depth is boiled off one foot deep, there in the ſhallow boiler, the whole buſineſs is finiſhed, and yet the latter doth contain 336 gallons, and the firſt but 288. And if the ſhallow boiler is 12 feet in length, 10 feet in breadth, and one foot deep, it will contain 726 gallons, and the ſurface will be 120 ſquare feet, and conſequently riſe ten times more ſteam; and the buſineſs will be done in a tenth of the time, and by ten times leſs fuel; that when in the common boiler, copper or pan of 4 feet diameter and depth, is boiled away one foot deep, there in the ſame time, and by the ſame fuel, muſt and will be boiled down that ſhallow boiler of one foot deep; and not only the whole buſineſs finiſhed, but alſo almoſt three times as much done as the whole boiler, copper or pan, of 4 feet diameter and depth doth contain; whereof now hath been boiled off one fourth part, or one foot deep, and there remain three more ſtill, for the further continuation of boiling, and before this is wholly finiſhed, the whole operation in the ſhallow boiler can be done four times, and each time 726 gallons, which amounts to the ſum of 2904 gallons, inſtead of 288, which is a ſurpriſing difference, being in proportion of ten to one.

And the ſame thing muſt alſo be underſtood in great diſtilleries, where the intent and purpoſe is ſolely to drive out of the fermented maſh the ſpirit into a ſteam by the help of boiling. But there cannot riſe more ſteam, than is permitted by the extent of the ſurface of the boiling maſh in the ſtill. So much as the ſurface is enlarged, ſo much time and fuel will be ſaved. If the common ſtill is 6 feet diameter and 7 feet deep, but only filled 6 feet deep, the contents do amount to 648 gallons, and the ſurface is only 27 ſquare feet. But if the ſtill was made ſhallow of 12 feet in length, and 9 feet in breadth, and 18 inches, or 2 feet deep, and filled only 1 foot deep, there the contents would be likewiſe 648 gallons, and the ſurface 108 ſquare

feet,

feet, which is more than in the common deep ſtill; conſequently when this is diſtilled off about one foot deep, there in the ſame time, and by the ſame quantity of fuel, the whole buſineſs muſt be intirely finiſhed in the ſhallow ſtill; and thereby five parts of time and fuel would be ſaved, which muſt be further ſpent to finiſh the work in the common deep ſtill.

In the ſugar-plantations this my changing of the deep coppers into ſhallow boilers will be of the greateſt benefit and advantage. Becauſe the liquors preſſed out of the ſugar-canes is very thin and like water, and by the hot ſeaſons common in thoſe iſlands, very liable to a quick and ſudden fermentation in leſs than half a day, and thereby made unfit for ſugar. Therefore they muſt make haſte to boil it, and to drive off the ſuperfluous moiſture as quick as poſſible. To this end they do force it with fire, made and kept commonly by the ſugar-canes being preſſed out and dried, giving a very fierce flame; but at the ſame time they alſo induce a burning taſte and ſmell, and a very dark brown colour, which greatly leſſens the value and price. All the operations are done at preſent in large deep coppers, *nine in number*, and often all the coppers are burnt down in one year. On the contrary, if they would uſe ſhallow boilers, containing a larger quantity of the ſweet juices, and having ſix, eight, or ten times larger ſurface than the preſent coppers; the ſuperfluous moiſture muſt alſo be driven off ſix, eight and ten times quicker, and even by ſo much leſſer fuel: but not to over-hurry the ſweet juices with fierce firing and boiling, they could by this method allow double the time, and nevertheleſs the operation would be finiſhed in a third, fourth, or fifth part of the time, as well as fuel; becauſe the ſurface is ſix, eight, and ten-times larger; and yet produced more than double the quantity of ſugar of a fine white colour, without a burning taſte and ſmell, and conſequently of more worth and value.

Chemiſts know very well, what bad effects immo-

derate boiling hath in colour, ſmell and taſte, in their extracts, conſerves and ſyrups. Treacle is no produce of nature, but ſolely of immoderate boiling, which is alſo witneſſed by colour, taſte and ſmell. If it was the produce of nature, there could not be found any French white ſugar, nor the refiners bring the brown to a white loaf ſugar, which is done by ſeparating the treacle. The beſt refined white ſugar ſmelted in a ſaucepan turns black, and then add ſome water for its ſolution, and hereafter boiled to a ſyrup conſiſtence, will become a treacle in colour, taſte, and ſmell, and though it may be brought by fire to a dryneſs; nevertheleſs it will grow moiſt again in the air, and very quickly too. All fruits, all extracts, all colours, all kinds of ſalt dried by fire and heat, do always grow moiſt again and wateriſh in the air, which they do not when they grow dry on their own account. And thereby may be underſtood the reaſons why the brown ſugar coming from the iſlands is moiſt and wateriſh, and one more than the other; and alſo why one kind of common ſalt grows moiſt and runs quickly into water, and another remains hard, and melts exceeding ſlowly in the air. The proper reaſon is this, that the latter, after the dropping hath been ſet aſide, has been allowed a ſufficient time to grow dry on its own accord; on the contrary, the firſt hath been carried into a ſtove and dried by exceſſive heat, that it may be quickly carried to the market and turned into money. Indeed it is made thus dry, that it rings as a bell when ſtruck, but coming in the free air, it grows moiſt again, and as quick as it was heated dry, and runs into water. This fault is not from nature, but doth proceed from the ignorance and over hurry of men. Nature can be helped in her works and products by thoſe who know and underſtand them; but never forced without damage, either to buyer or ſeller, and finally to both.

Here I muſt alſo inſert another obſervation: the greater

greater the length and breadth of ſhallow boilers, the more agreeable and convenient to my invention of ſetting them. But if the ſhallow boilers come above 10 and 12 feet in length, and 8 or 10 feet in breadth, then they become very troubleſome in workmanſhip as well as the carriage to and fro, and likewiſe in ſetting and working them. Therefore it will be more convenient and advantageous to divide a large deviſed ſhallow boiler in three or four ſmaller boilers, of a moderate length and breadth, that they hereafter may be ſet either one next to the other, or left between each a way of about a foot or 18 inches broad; and yet all upon one furnace and flue; and alſo ſerved and wrought by one fire; and by the ſame quantity of coals will be produced double or treble the quantity more than by the common and preſent method, which will be very advantageous and profitable in ſalt-works, as well as in ſugar, allum, copperas, vitriol, and ſalt-petre works.

But amongſt all the before-mentioned caſes, and different works and buſineſs; this my new invention will be of the utmoſt ſervice and benefit in fire-engines. For all the others are moſtly intermittent works; that is to ſay, ſuch which are undertaken only one or two days in a week, or one or two weeks in a month, or quarter of the year, or at a certain ſeaſon in a year: but in fire-engines, and even in ſalt-works, the fire is kept in day and night throughout the whole year; and there is burnt and waſted in both a very great and amazing quantity of coals. Nevertheleſs, the quantity of coals burnt and waſted in ſalt-works, muſt be accounted as a very moderate one in regard to the fire-engines, where the great waſte of coals doth ſurmount that in the ſalt-works, more than four or five times. The reaſon whereof is not the difference of the work, but ſolely herein, that in the ſalt-works, and ſetting in the boilers, they have employed ſome reaſon, but in conſtructing and ſetting the boilers at the fire-engines abandon all ſound reaſon, and turned every part

into the greateſt exceſs. The boilers are of different dimenſions. I will take for an example a boiler of 9 feet diameter at the bottom, from thence to the flange 3 feet high, at the flange 12 feet diameter, and from thence to the leaden cover again three feet. Such a boiler is not the ſmalleſt; indeed, nor yet the biggeſt. It is commonly filled a foot high above the flange, and conſequently the depth of water therein is 4 feet; and the whole quantity doth amount to 29 hogſheads, and the ſurface to 108 ſquare feet.

Now, how is ſuch a boiler ſet at preſent? The grate is ſo large as the bottom of the boiler, that it meaſures 9 whole feet in ſquare, amounting to 81 ſingle ſquare feet, through which the air hath a free and uninterupted acceſs: about a yard from the grate ſtands the boiler, and there the fire-place is ſo large, that it cannot be filled with two tons of coals; the flue round about the boiler is not bigger, but only 3 feet high, and about 18 inches wide, that it reſembles perfectly a ſide-hole of mount Etna; and to fill a whole river of fire and flames would ſcarcely be enough. Indeed, the exceſs of proportion is too great and enormous in every part, and the whole hath no other face, than if it were profeſſedly conſtructed for the ſole and whole intent of burning and waſting the greateſt quantities of coals that human ſkill and ingenuity could poſſibly invent: I am not ignorant of what is ſaid in excuſe for widening the fire-place and flue, but I cannot account it ſufficient; for I could ſhow, that the cleaning of the flue, and mending of the boiler could be contrived in a better, eaſier, and more durable manner, without enlarging the fire-place and flue to ſuch enormous exceſs. But to be ſhort, I will only aſk, whether it is a wiſe and prudent proceeding, or a moſt fooliſh one, when the firſt and principal intent is laid wholly aſide, and intirely loſt, for obtaining a ſecondary one? The firſt and principal intent in ſetting boilers is this, that the water in the boiler may boil as quick, and with as ſmall a

quantity

quantity of coals as poſſible. The ſecondary intents are the cleaning of the flue once in two or three months, and the mending of the holes burnt in the boilers once in four or five years. For obtaining theſe ſecondary intents, the fire-place and flue are widened above all convenient meaſure, and into a moſt enormous largeneſs; and thereby is intirely loſt the firſt and principal intent, which now cannot be recovered and obtained, but by burning and waſting treble the quantity of coals. Therefore the proprietors muſt pay very dear for the cleaning of the flue, only once in two or three months, and for mending the boiler, which ſeldom needs it before the fourth or fifth year; and yet the ſuperfluous waſting of enormous quantities of coals does begin the very firſt day, and continues day and night throughout four or five years, before the neceſſity of mending the boiler does exiſt; and in the mean time, every year burns and waſtes ſo much in coals as an entire new boiler is worth. Who can but approve therefore of ſuch a very ſkilful and advantageous contrivance and improvement?

But to return to the ſubject treated of above, where I mentioned the boiler was filled with water 4 feet deep, which did amount to 29 hogſheads, and the ſurface to 108 ſquare feet. Now what is the proper intent and purpoſe hereof? Perhaps to boil only a large body of water? Or to convert only the water into ſteam for pleaſure, paſtime, and burning coals? By no means; but principally and ſolely to raiſe a ſufficient quantity of ſteam from boiling water, by the ſmalleſt quantity of coals poſſible, that therewith may be filled the cylinder to counterbalance the preſſure of the atmoſphere, that the piſton may riſe and aſcend. And to that end, all the parts in conſtructing and ſetting the boilers ſhall and muſt ſtraitways be directed, and meet together like the lines from the circumference to their proper center.

Now the ſufficient quantity of ſteam does depend not from

from the depth and the great body of the water, but ſolely and alone from the ſufficient extent or largeneſs of the ſurface of the boiling water. A cylindrical veſſel filled with water 2, 3, 4, 5 or 6 inches, and boiled, will give as much ſteam as when filled 1, 2, 3 or 4 feet deep, and in all thoſe nine caſes, the riſing quantity of ſteam will be always one and the ſame, becauſe the ſurface is one and the ſame. And hereby it is farther to be noted, that in the firſt five caſes the water will boil far ſooner and with far leſs fuel, than in the four latter caſes, wherein it will take up three or four times that time, as well as fuel. Is it not now to be counted a great folly, when the boiler for riſing ſteam is filled with water four whole feet deep, and yet therefrom cannot riſe more ſteam than when it is filled with water 6 or 3 inches deep, ſuppoſing the ſurface was of equal extent; which latter will boil quick and by a ſmall quantity of fuel, when the firſt cannot be made boil in ſeveral hours, and by treble or four times that quantity of coals or fuel.

Therefore I do change the preſent boilers at the fire-engines with very ſufficient reaſons into ſhallow boilers; and inſtead of the before-mentioned old boiler, I do conſtruct a ſhallow one, of 16 feet in length and 8 feet in breadth, and 2 feet and a half deep: two feet hereof do belong to the confinement of the ſteam, and half a foot for the depth of the water. In this, my new boiler, the whole depth of the water doth amount to 7 hogſheads and 6 gallons, inſtead of 29 hogſheads in the before-mentioned old boiler, the hogſhead accounted to be 54 gallons; and the ſurface of the water doth amount to 128 ſquare feet, inſtead of 108 in the old boiler, and conſequently 20 ſquare feet, and alſo one fifth more: and yet this, my ſhallow boiler, will coſt in iron-plates and workmanſhip, near one quarter leſs than the old boiler mentioned before. And that from 128 ſquare feet ſurface, muſt riſe more ſteam than from 108 ſquare feet, viz. One fifth part more, and

alſo 7 hogſheads of water being only 6 inches deep, muſt boil quicker and with far leſs fuel than 29 hogſheads, being 4 whole feet deep, no body of ſound ſenſe will call in queſtion.

This changing of the large deep boilers at the fire-engines, in proportionable ſhallow boilers, is in order, the firſt part of my new invention, which contributes ſomething to the great effect, and paves the way for the ſecond part, which is properly the firſt and principal cauſe whereon here, and alſo in all the fore-mentioned ſhallow boilers, in the different buſineſſes and works, doth depend, and produce the great deſired effect of ſaving more than the half part of coals or fuel burnt and waſted, and of obtaining a quicker and larger diſpatch in every reſpect.

And that ſecond part, in order of my new invention, but the firſt and principal in regard of the effect, doth conſiſt in a peculiar method of ſetting all the fore-mentioned boilers upon a ſmall furnace and ſerpentine flue, in ſuch a well-contrived manner, that the fire goes out of the furnace in full flames under the whole bottom of the ſhallow boiler, a way of about 100 feet, and then alſo through the chimney till it comes to the top before it eſcapes into the open air. The furnace-flue and chimney are regulated according to the different dimenſions of the ſhallow boilers, and they altogether in a geometrical proportion one with the other. And this point coſt me ſeveral expenſive experiments, and different alterations in them, before it could be diſcovered and accurately determined.

Eſt modus in rebus, ſunt certi denique fines
Quos ultra citraque nequit conſiſtere rectum.

That is to ſay, All things have their properties, certain meaſure and proper terms: a little more or leſs will make the whole uſeleſs, ineffectual, and contrary to expectation.

Two regulators are added, one for regulating the acceſs of the free air, and the other for regulating the exit

exit of ſmoke, fire, and flame. The materials for the furnace and flue are good fire-bricks, Stourbridge or Windſor clay, or any other fire-ſtanding loam. The cleaning of the flue is contrived thus, that it can be done very eaſily in one hour by one man, when and ſo often as it is thought proper. The mending of the boiler can be done eaſily, commodiouſly and very durably.

Moreover the whole can alſo be fitted up for any intent and purpoſe, and different degrees of fire and heat, as well as alſo for the uſe of different kinds of fuel, that pit-coals, turf, peats, goaſs, canes, ruſhes, heath, faggots and ſplit-wood, nay any thing or matter, which will burn and flame, may be uſed for the different intents and works with great advantage and benefit. But when candle, coals, coaks burnt from candle, or pit-coals, and chair-coals, ſhall and can be the fuel, there I procure a great commodity and eſpecial advantage by building a coal-magazine, containing and to be filled at once with about half a ton, either more or leſs, as it will be deſired, and whereof by itſelf and without all help of hands the fire is ſucceſſively fed, and will laſt from 24, 36, 48, to 60 hours, according to the degrees of fire given, and without any neceſſity of adding any fuel more in all that time, by which is obtained a conſiderable advantage, for the workmen can ſleep and reſt in the night without any fear, that the fire will go out, the boiler grow cold, and the work ſtop. And whereas it is impoſſible to know beforehand, all the different intents and purpoſes of the curious gentlemen artificers, and alſo the different kinds of fuel next at hand on every place, therefore it is alſo impoſſible to ſay any thing more here on that ſubject, but it muſt be left ſolely to my ingenuity of ſatisfying every one in particular according to his particular intents and purpoſes.

About the ſhallow boilers I will obſerve, that the cóver to them may be made of lead, iron-plates, oak-

planks,

planks or red-deals, according to the option of the proprietors, and alſo whether the cover ſhall be arched, or plain and level, with or without a manhole, for that will make no difference with me. Inſtead of gage-cocks, I have invented a ſimple machine, which will ſhew at all times the depth of water in the boiler to a quarter of an inch, with the greateſt accuracy. All the other parts remain the ſame with the old boilers.

I am fully perſuaded, that I have given to the wiſe and underſtanding part of mankind, ſufficient accounts of my new invention. And if any one will not be ſatisfied, and put more queries to me, he may expect from me no further anſwer or explication. I have not been always cautious enough in diſcourſing about ſhallow boilers and the depth of water, but have let ſlip ſome expreſſions, by which ſome perſons having taken the hint, went into the country and made a ſhallow boiler, and in all ſecreſy ſet it upon a furnace and ſerpentine-flue, according to their own fancy and imagination; but ſo great was their diſappointment, that they now carefully conceal their folly. At another time I ſaid, that the cylinder might be made from oak-planks, no more being required but to be air-tight, and alſo the piſton of the ſame ſtuff, and inſtead of the ropes round about the piſton I could uſe cork, which alſo was the beſt ſtuff for the piſton in the barrel of an air-gun. Directly was this ſecretly undertaken and made a trial of in the country, with the intent to find it out, and get hereafter a patent: but they found themſelves miſtaken greatly. Becauſe the firſt inventors have always ſome peculiarities and ſecrets of which counterfeits are totally ignorant. I am a ſtranger, and like a ſheep among wolves; if the hand of God had not protected me, I ſhould have been devoured a long time ago. Therefore I muſt proceed, wiſe as the ſerpent, and without all falſhood like the dove. My ſhallow boilers have ſome peculiar properties, by which they are diſtinguiſhed from all others exiſting at pre-

ſent in the world; though I have ſaid not one word, yet, conſequently a malicious ſchemer cannot know any thing thereabout. Moreover I ſay, without any arrogancy, that I am the firſt in 5000 years, or in all the world, who hath found out and diſcovered a geometrical proportion between a furnace and the body of fire, and the flue and chimney, that a ſmall quantity of fuel gives a great fire and flame, which goes in a body a way of above one hundred feet, and produces the deſired effect, though it will be incredible. It is the firſt ſtep, which I have done, and it will admit of improvements without all doubt, though I cannot ſay any thing more thereabout now. Nevertheleſs, every one will conceive and underſtand, that out of this my invention, will ariſe and accrue, the greateſt advantages to all uſes and works in fire, and alſo in furnaces of melting ores or metals. Therefore I will leave to the judgment of the public, whether I deſerve to be expoſed and left to the injuries, abuſes and oppreſſions of inſatiable, covetous ſchemers, or to be protected and encouraged by all the patrons and lovers of uſeful inventions. *Sed haec in parentheſia.*

No one will judge it improper, to ſay ſomething more of the quantity and rarity of the ſteam in the boilers, as alſo of the weakneſs and ſtrength of the ſteam. About the quantity and rarity of the ſteam, the accounts have been made always too high or too low. The beſt of all I have met with, is found in the New Royal and Univerſal Dictionary of Arts and Sciences, under the title of Engine, where it is written thus:

" Mr. Henry Heighton made an experiment to de-
" termine the rarity of the ſteam, and found the con-
" tents of his barrel (or cylinder) to be 113 gallons;
" and ſince there were 16 ſtrokes in one minute,
" therefore 113X16—1808 gallons of ſteam per minute.
" He alſo obſerved, that the boiler required to be ſup-

" plied with water at the rate of 5 pints per minute; " and ſince 282 cubic inches make a gallon, 35¼ one " pint. Then 5X35¼—176¼ in 5 pints; alſo the cubic " inches of ſteam are 1808X2282—509856: if we then " ſay, as 176¼:509856::1:2893, or 1 cubic inch of water " is expanded into 2893 cubic inches of ſteam; con- " ſequently the ſteam in the barrel (or cylinder) is re- " duced to $\frac{1}{2893}$ part, when turned to water by " the jet of cold water; and therefore a ſufficient va- " cuum is made in the barrel for the piſton to deſcend " unbalanced by the preſſure of the air."

Hereof can be made eaſily the account for the neceſſary ſurface of the water in the boiler, and alſo for the quantity of water wherewith the boiler muſt be filled and ſupplied, if the contents of the cylinder are before known. But the due diameter of the cylinder and its contents, may be found out by another way and method.

Concerning the weakneſs and ſtrength of the ſteam, there is ſaid and written very much, but with very little ſatisfaction. For it is ſaid, in the ſame place, " The " ſteam firſt ruſhing in the cylinder, is a little ſtronger " than the outward air, and will drive the air in the " bottom of the cylinder out by the ſnifting clack, but " the ſteam cannot follow, becauſe the ſteam is weaker " than the air." Herein is a manifeſt contradiction. Further is written in the ſame place. " Leſt the " ſteam ſhould grow too ſtrong for the boiler, and " burſt it, there is a little valve (called the puppet- " clack) to put a weight of lead upon, by which to " inquire the ſtrength of the ſteam. Thus the ſteam " is known to be ſo ſtrong as the air, if it will raiſe up " ſo much weight on the valve, as it is at the rate of " 15lb. to an inch ſquare, becauſe that is the weight " of air very nearly on every ſquare inch, when " the ſteam becomes ſtronger, it will lift up the clack " and go out." But all this doth ſeem to me a very paradox.

 I can-

I cannot conceive, how there can be any fear of burſting boilers, when the preſſure of air upon each ſquare inch round the boiler is at the rate of 15lb. weight, which will keep the boiler ſtrong together, like iron-hoops. Doth it not ſeem, that the aſſertors of a conſtant and unintermitting preſſure of the air were afraid that it might not withſtand the preſſure of the ſteam? And when on the valve is laid 15lb. of lead on every ſquare inch, and the ſteam lifting it up, why can this be accounted, that the ſteam was as ſtrong as the air? The account is erroneous indeed, becauſe it is ſaid, that the preſſure of the air was on every ſquare inch very nearly at the rate of 15lb. and then is added on every ſquare inch 15lb. of lead, which both amounts to 30lb. and the clack being lifted up by the ſteam, there is abſolutely an evident proof, that the ſteam muſt be two-fold ſtronger than the common air; becauſe the ſteam over-balances not only the preſſure of the air at the rate of 15lb. on every ſquare inch, but alſo 15lb. of lead. But if the firſt accounts ſubſiſt and be defended, then it is thereby given us to underſtand, that the preſſure of the air muſt be never taken in ſuch and the like account, becauſe it doth conſiſt in a ſuppoſition and pre-conceived opinion. Further it is written thus, "The ſteam is always of a variable ſtrength, but never one-tenth ſtronger or weaker than common air." Though the accounts do ſeem very accurately made and brought into broken numbers, nevertheleſs I cannot avoid thinking: *Interdum et dormitat bonus Homerus.*

I am fully convinced, and do willingly grant, that the air hath a power of preſſing towards the center. I alſo grant that the preſſure of the air upon a vacuum is at the rate of 15lb. on every ſquare inch; but that the latter ſhall alſo be the meaſure and weight of the firſt, and alſo be made to a conſtant quality and unintermitting effect, I cannot underſtand, or conceive,

ceive, and far leſs that it can be made to the meaſure and weight of the ſteam. Becauſe that weight of the preſſure of the air is ſolely to be obſerved in the one only particular accident of the exiſtence of a vacuum, and no where elſe in nature. Therefore the ancient philoſophers ſay: *Non datur vacuum in natura.* And the modern have not yet proved the contrary. All vacuums are artificial, and produced by ſkilful machines. But what is this for a ſyllogiſm? The preſſure of air upon a vacuum is on every ſquare inch at the rate of 15 lb. of lead: therefore the air preſſes every where, and continually upon each ſquare inch at the rate of 15 lb. of lead: but, *A particulari ad univerſale non valet conſequentia*, which is a very old rule in Logic, and not yet overturned.

Beſides this may be conſidered, a common pump; if the piſton or pump-rod is raiſed, there begins to exiſt a vacuum, and then at the ſame moment the air preſſes upon the ſurface of the water in the well, and forces the water up and above the clack, a height of about 32 feet, and filleth the vacuum up with water. If now this preſſing force was a conſtant effect of the air, then muſt alſo conſtantly the water be forced up, and run out without the neceſſity of a clack, ſucker, and pump-rod and its working, which yet is not, and thus an evident proof, that this preſſing force, at the rate of 15 lb. on each ſquare inch is not a conſtant and unintermitting quality and effect of the air, but only and ſolely exiſting at the particular and artificial accident of a vacuum.

The elements work according to the nature of the objects which they meet with. The fire hardens the bricks, ſmelts the metals, and turns wood in aſhes, and this in a glaſs. The water cleans the linen, ſoftens clay and loam, and hardens the hot metals. The air is light, and let every thing move eaſily without any ſenſible reſiſtance; but meeting a vacuum, its preſſure is ſurpriſing and inconceivable. The wiſdom of

the

the Almighty hath weakneſs and ſtrength therein conjoined. For in the air is a ſecret food of life, without which neither animals, vegetables, nor minerals can live, grow and ſubſiſt; and therefore he hath empowered the air to fill up all the vacuum upon and in the profundities of the earth, that the whole may become full of the goodneſs of God.

Laſtly, I aſk the aſſertors of the conſtant and unintermitting preſſure of the atmoſphere upon each ſquare inch, at the rate of 15 lb. lead, how a cow and horſe could bear ſuch enormous weight, without being cruſhed into the ground, but move ſo eaſily and ſwiftly? To this is commonly anſwered, that the air in the animal does counter-balance it ſo, that it cannot be felt. But I aſk further, how much air is then in thoſe animals, beſides blood, fleſh, bones, ſerum, veins, arteries, excrements and urine, and that all compaſſed in one ſkin, doth not that all counter-balance the preſſure of the air? Without doubt. But inſtead of enumerating ſo many things, whereof the animal is full, would it not be ſhorter to ſay, there is no vacuum in the animal: which alſo would be the proper reaſon, agreeing to the nature of things.

I will ſtop in this matter, and rather inquire for the true and proper cauſes of the weakneſs and ſtrength of the ſteam. For if we know the proper cauſes, we ſhall be able to produce the effects, and regulate them for our intents and purpoſes. I have never heard or read any thing thereabout, and I am alſo ſure, that nobody doth know otherwiſe. But being meditating thereupon, there was communicated to me by an old and experienced engineer the following experiment.

Take two tea kettles exactly equal one to the other in diameter, as well as in depth. Fill the firſt with water two inches deep, and the ſecond four inches, and then ſhut both with their covers, wherein may be a very ſmall hole for the ſteam, and ſet them upon an equal fire in one and the ſame moment. There will be

be found, that the firſt will boil ſooner and quicker than the other, but give a very weak ſteam; but when the ſecond doth likewiſe boil, it will give a double ſtronger ſteam then the firſt. Therefore the deeper the boiling water, the ſtronger the ſteam, and the ſhallower the boiling water, the weaker the ſteam.

The truth of the experiment I granted without making any trial thereof, but the concluſion I abſolutely rejected, and oppoſed another experiment of this manner.

Take two tea-kettles exactly equal in diameter, but of a different depth, one three inches deep, and the other eight inches deep. Fill the firſt with water two inches deep, and the ſecond four inches deep, put upon them the covers, having a very ſmall hole, and ſet them upon an equal fire in one and the ſame moment. And there will be found, that the firſt will boil almoſt immediately, and give a ſtrong ſteam burſting out with an hiſſing noiſe, when the ſecond is ſcarcely warm, and when it laſtly comes to the boiling, the ſteam will be found four times weaker than in the firſt. Therefore the ſhallower the boiling water the ſtronger the ſteam, and the deeper the boiling water, the weaker the ſteam.

Both experiments are true, and will be found ſo always in practice thus; and yet the concluſions drawn therefrom are diametrically contrary one to the other, and both erroneous too. For by over-hurried and ſuperficial conſidering is taken up, *non cauſa pro cauſa*, which I will ſhew evidently. In the firſt experiment the tea-kettles were exactly equal one to the other in diameter and depth, ſuppoſed ſix inches, and when the firſt was filled with water two inches deep, then was left room for the ſteam four inches; and when the ſecond was filled with water four inches deep, then did remain for the ſteam only two inches. Conſequently the ſteam in the ſecond kettle was found two-times ſtronger then in the firſt, and this gave a two-

times,

times weaker ſteam then the ſecond, becauſe the confinement of the ſteam was two-times larger than in the ſecond. On the contrary, in the ſecond experiment is found, that the kettle filled with water two inches deep gives a far ſtronger ſteam and blaſt than the ſecond kettle filled with water four inches deep, not by reaſon of the ſhallowneſs or depth of the boiling water, but ſolely by reaſon of the confinement of the riſing ſteam, which is in the firſt one inch, and in the ſecond four inches, and juſt four times more.

Every one will underſtand and willingly grant, that the ſteam in a veſſel of the meaſure of 20 hogſheads cannot be ſo ſtrong as when the ſame quantity of ſteam is brought into a veſſel of a meaſure of 10 hogſheads; and again, not ſo ſtrong as when the ſame quantity of ſteam is confined in a veſſel of the meaſure of 5 hogſheads; and again, not ſo ſtrong, as when the ſame quantity of ſteam is confined in one hogſhead. Therefore I will ſet here down four axioms, being univerſal truths, admitting no contradiction.

I. The quantity of ſteam doth depend neither from the depth nor ſhallowneſs of the boiling water, but ſolely from the extent of its ſurface and quantity of the ſquare feet thereof. It is very comprehenſible, that from 100 ſquare feet ſurface of boiling water muſt riſe double more ſteam then from 50, and from thoſe twice more than from 25, and from thoſe 25 times more, then from one ſquare foot, and thus *vice verſa*.

II. The ſufficiency of ſteam doth ſolely depend on the ſufficient extent of the ſurface of boiling water. If the ſteam raiſed from 100 ſquare feet ſurface, proves ſufficient for the purpoſe, no body can reaſonably expect, that 50 or 25 ſquare feet ſurface would be even ſufficient.

III. The ſhallower the water, the quicker, and by leſſer

leſſer fuel it will be made boiling and emitting ſteam: on the contrary the deeper the water, the longer time, and the more fuel muſt be ſpent, before it can be brought to the ſteaming and boiling. This truth is already known to all kitchen maidens.

IV. The riſing ſteam from boiling water is always thin and weak: but in a firm and cloſely covered veſſel, it will grow to ſeveral different degrees of ſtrength and force, proceeding and depending neither from the depth nor ſhallowneſs of the water; but partly from the length of time in boiling, when the ſteam is conſtantly increaſed, augmented and ſtrengthened, partly from the different compaſs of its incloſure and confinement. The larger this is, the weaker the ſteam; the narrower it is, the ſtronger the ſteam; and when too narrow, then the ſteam will prove of ſuch an aſtoniſhing power and ſtrength, that will burſt and break the ſtrongeſt metalline walls of its priſon, in the ſame manner and force that gun-powder burſts a bomb.

This latter effect of the ſteam is ſhown firſt, by the inſtrument called Aeolopile: conſiſting of a ſhallow metalline ball, with a ſmall pipe or neck ſcrewed to the ball. This hydraulic inſtrument, if filled with water and expoſed to the fire, will produce a ſtrong blaſt of wind, or rather an elaſtic ſteam and vapour, with a hiſſing great noiſe. This hath induced many to ſubſtitute it for a pair of bellows, to force the fire into an intenſe heat by the ſtrength of the blaſt; but the trial hath proved the contrary, that that ſtrong blaſt inſtead of kindling the fire, hath extinguiſhed, and put it out intirely.

Secondly and more evidently, it is proved by the machina pappiana, being an inſtrument made of copper, iron, or braſs, containing about three or four quarts, and can be cloſely ſhut with a cover by the help of ſeveral ſcrews, that nothing can enter in or go out. If the hardeſt ox-bones are put into that machine with

a due quantity of water, ſcrewing the cover down cloſely, and then ſet upon the fire and boiled about 2 ½ hours, the ſteam will act ſo forcibly upon the water, and preſs it into the pores of the bones, that their coheſion is broken, and their whole ſubſtance diſſolved into a jelly, which effect hath been never produced by the preſſure of the air, and conſequently the ſteam muſt be capable of being carried to ſuch a degree of ſtrength overtopping that of the preſſure of the air. But here muſt be alſo remembered further, that when in that machine there hath been poured too much water, and left for the ſteam too little room, that the ſteam hath proved of ſuch great power and ſtrength, as to burſt and break the machine in pieces, have been violently ſcattered about, and ſome of the bye-ſtanders dangerouſly wounded, and ſome killed.

Thirdly, It is a query, wherein properly do conſiſt the moſt ſurpriſing and aſtoniſhing power and ſtrength of all gun-powder, being the maſter-key for opening all locks, bolts, gates, and ſtrong-holds. I cannot remember to have heard or read a due and ſatisfactory account thereof; and thus others muſt ſay likewiſe. Nevertheleſs I do declare frankly, that all the ſurpriſing and aſtoniſhing power and ſtrength in one pound of gun-powder, doth properly proceed from ſteam ariſing by an inſtantaneous and ſudden diſſolution of four ounces and one drachm of water, being a conſtituent eſſential part of 12 ounces of cryſtalline nitre, which with two ounces of brimſtone, and two ounces of charcoal-duſt do by long grinding, compoſe one pound of gun-powder. The charcoal-duſt catches the fire and communicates it to the brimſtone, and the inflammable matter lurking in both, is kindled and therewith the nitre, and the whole ſet in fierce fire, by which the four ounces and one drachm of water is inſtantaneouſly diſſolved into a ſteam, which now abſolutely requires 2893 times larger place for its expanſion, than it had when water; and therefore it breaks

and forces through all the ſtrength of its priſon, and burſts out where is leſſer reſiſtance, and throws about every thing in the way. May it now be ſaid and written, the ſteam is never one-tenth part weaker or ſtronger than common air? But enough of this.

I come now to the concluſion, wherein I ſhall give advice of the conditions. I am by no means for employing my invention in any buſineſs to my ſole and private uſe and benefit; but the patent being graciouſly granted to me for the good of the public, it alſo ſhall be the principal mark to which all my endeavours ſhall be directed. If now any one will accept of, and make uſe thereof, he will be pleaſed to write to me thereabout, and give me advice of his particular intents and purpoſes, and I will anſwer accordingly.

If any one writes to me concerning fire engines, there muſt be mentioned in the letter, whether it is an intire new one, or an old one, wanting only a new boiler. If it is an entire new one, then I muſt be adviſed accurately of the depth of the engine-pit, and how much water muſt be diſcharged in one hour; and then I will ſend back the direction of every particular part belonging thereto. But if it is an old one, and wanting only a new boiler, then I muſt be adviſed of the diameter and depth of the cylinder, and alſo of the diameter of the old boiler above the flange, with remarks, whether the ſteam hath been ſufficient enough or not, and then I will ſend back the direction in a letter.

If it doth concern the ſalt-pans in the ſalt works, there I muſt be adviſed whether the purpoſe is for making more fine or middling, or more coarſe ſalt; and alſo the room and extent of the ſalt-work, and then I ſhall give the direction and anſwer accordingly. And even the ſame advices are required in ſugar, allum, coperas, vitriol and ſaltpetre works.

But when it does belong to brew-houſes and diſtilleries, there I muſt be likewiſe adviſed about the eſpe-

cial intents and purpoſes, in regard to the quantity of liquors and ſpirits intended, and then I ſhall anſwer accordingly to all particulars requeſted.

And if any curious gentlemen deſires any advice or direction for the uſe and application of fire in any degree for particular intents and purpoſes, if he will be pleaſed to give me advice thereof, I will endeavour to anſwer him to his ſatisfaction.

Moreover I muſt alſo declare in general, that I will always decline the direction of the places and workmen employed in any thing and matter, and never make a low bargain with the work and a long bill to the maſters, which I do account an impoſition upon both. But all the proprietors and maſters ſhall have the liberty to beſpeak and let every thing be made on a place and by workmen at their own option and account. And though I may be deſired to give directions for a new fire-engine, nevertheleſs I ſhall make neither any charge thereabout, nor meddle myſelf with the erection thereof, never intending to deprive any one of his bread, and put it in my mouth; but the proprietors ſhall be at full liberty of employing any engineers as they think proper, and I will always keep within the rails of my patent, and abide by the ſole ſetting of the boilers, and come thither as ſoon as I am adviſed, that every thing is on the ſpot.

All letters (poſt-paid) ſhall be duly anſwered, and according to the date wherein received: they ſhall alſo be ſerved accordingly, and I ſhall let none perſuade me to prefer one before another, contrary to the order above-mentioned.

My direction is, To Chriſtopher Chryſel, at Mr. William Gant's, bookſeller and ſtationer, in Corn-ſtreet, Briſtol. By which direction all letters (poſt-paid) will come to my hands.

Laſtly, for my part and payment I do deſire and inſiſt upon the three following points:

1. The

1. The expences of my journey to and fro to be paid me.

2. My lodging and boarding as long as I am from home, which will be always a very ſhort time, if I am not hindered by the want of materials, which ſhould have been provided before.

3. Though according to the tenor of my Royal Letters Patent, I am intitled to all the benefits and profits, coming, growing, accruing and ariſing by my new invention, nevertheleſs I am ready to let the proprietors ſhare with me; and if I did call for the half part thereof for 14 years, they could not well blame me. But I will come lower down, and demand

At the fire-engines on mine-works, only the ſaving of coals and fuel the firſt year, and all the following years I will wholly leave to the proprietors.

At the fire-engines on coal-works, where the coals are commonly of a very low account, I ſhall aſk for the ſaving of coals the firſt three years.

N. B. 1. If a fire-engine hath two boilers which are fired at once, I muſt alſo account them for two: but if they are uſed alternately, then I do account them but one.

2. Where I have ſet a boiler once, and am paid for it, I ſhall never deſire any thing, if in the courſe of 14 years it ſhould happen, that a new boiler muſt be ſet again; and the proprietors ſhall be at liberty to do as they pleaſe, and employ any hand therein, and when they will write to me thereabout, I will come or ſend one of my deputies, and there charge no more but what are the common expences at the preſent and in the foregoing times.

At the ſalt-works, and all the other branches of buſineſs agreeing in ſome way therewith, I will demand only the clear profit coming, growing, accruing and ariſing by the ſaid invention the firſt year, and leave all the ſubſequent years wholly to the proprietors. And that this

this may be the better underſtood, I give this explication thereof.

If at the preſent, by 5 tons of coals are made 9 tons of ſalt in a week, and hereafter by my invention and leſſer fuel are produced 18 tons of ſalt or more in a week, then it is manifeſt, that the ſurplus of ſalt is ariſing and accruing by my invention, which ſurplus, after the expences of workmanſhip has been deducted, I do call the firſt year ſolely mine; and all the ſubſequent years ſhall be left intirely to the proprietors. But if they do deſire to ſhare that profit alſo in the firſt year, I ſhall even move no great difficulties of ſharing the half part with them the two firſt years, which is even ſo much as the foregoing requeſt.

At the brew-houſes and ſugar-works I ſhall likewiſe deſire no more, but the benefits and profits coming, growing, accruing and ariſing by my invention, for the term of the firſt year.

I hope, that theſe conditions will be univerſally accounted reaſonable, equitable, honeſt and acceptable; for it is fully clear therein, that I do not deſire to be paid from any thing elſe, but by and from the effects and benefits of my own invention, and this only the firſt year, and all the following 13 years do fall to the benefit of the proprietors.

Finally, I would recommend myſelf to the favourable opinion of every reader, and give him this aſſurance, that on every occaſion I ſhall be found ready for his ſervice as much as doth lie in my power.

FINIS.

If any Gentleman will favour me with a letter, he may uſe this direction: *To Mr.* Charles Chryſel, *at Mr.* Lowe's, *ſilverſmith, in Mortlake, Surry:* And my ſon will ſend them to me at any place whereſoever I may be in employment or buſineſs.